

those operating on the proposed 30 MHz frequency assignments will start off at 200 kHz and increase to 2200 kHz. In addition to our other interference concerns, this added offset will result in spectral inefficiency because the assignment of adjacent channel stations may overlap to the extent noted above if each is operating on a different frequency plan. In those cases, the ability to clear potential interference through the use of cross-polarization may be lost."

ANS Comment: This concern has been resolved in the revised frequency plans.

(8/2) "To allow for most efficient use of this band, the proposed 30 MHz bandwidth channel frequencies should be changed to the 29.65 MHz spacing. Narrowband subdivisions of these channels, where necessary, may be produced by dividing the channel into equal parts; for example a 29.65 MHz wideband channel could produce three narrowband channels, each of slightly less than 10 MHz."

ANS Comment: This exact approach has been incorporated into the revised frequency plans. See Attachment A, Modified Plan at Section 3.2.

(8/3) "The NSMA agrees with the Commission's intent to permit the use of Automatic Transmitter Power Control (ATPC) under Parts 21 and 94 of its Rules. However, the proposed changes related to ATPC as detailed in the FNPRM are inadequate and confusing."

ANS Comment: ANS concurs. We suggest NSMA and TIA develop the criteria.

(8/4) "Three sections have been explicitly proposed for modification to permit ATPC: Section 21.710, Section 94.45 and Section 94.79. Two of these sections (21.710 and 94.79) deal with EIRP limits on short paths, while the other (94.45) states the conditions requiring modification of station authorization. None of these proposed rule changes reflects the current usage of ATPC systems."

ANS Comment: Clarification by the Commission is solicited.

(9/3) "The proposed modifications to Parts 21 and 94 mention 3 dB increases in EIRP in Sections 21.710 and 94.45. As discussed above, the EIRP of an ATPC system may change by much more than 3 dB as fading conditions are encountered. However, the maximum EIRP of an ATPC system (based on the maximum transmit power) would not change."

ANS Comment: Noted.

(9/4) "NSMA requests that the FCC modify the rules to allow for transmit power decreases below the maximum transmit power for ATPC systems if they are consistent with the operation specified during the coordination and licensing

process. However, the various maximum limitations on transmit power, EIRP, field strength, or power flux density by frequency band (as currently contained in the rules) must be met when the ATPC system is at the maximum transmit power. This will allow for the current protection afforded by the rules, while acknowledging that ATPC systems can operate over a range of transmit powers."

ANS Comment: Noted.

(9/5) "In order to allow a claimed coordinated transmit power to be below the maximum transmit power, NSMA guidelines require that certain restrictions be met. Due to the complexity of these restrictions, the NSMA feels that the Commission should allow industry associations (such as NSMA and TIA) to define appropriate procedures to be used in dealing with ATPC systems during interference analysis. This approach would be consistent with the approach to other interference related issues (see Section 21.100(d) and Section 94.63(c)(2))."

ANS Comment: ANS concurs.

(10/1) "The NSMA, in Attachment A, suggests changes to the rules to explicitly accommodate ATPC systems in Part 21 and Part 94."

ANS Comment: Noted and appreciated.

(10/3) "The Commission's continued efforts to negotiate with the NTIA to allow public use of these bands is an important and worthwhile effort for two primary reasons. First, there are likely to be some situations in which 2 GHz band fixed microwave is the only economic communications alternative; providing access to spectrum in the 1710-1850 MHz government band will allow relocation of these private fixed 1850-1990 MHz incumbents, permitting more homogenous access to this band by emerging technology proponents. Second, as has been suggested in congressional proposals, economies and spectrum efficiencies will accrue if both government and non-government users are able to share the same spectrum, especially if government users are able to take advantage of commercial offerings made possible by public access to government spectrum."

ANS Comment: ANS concurs.

Northern Telecom

(3/2) "Northern Telecom has continued to increase the efficiency of its microwave equipment, and has introduced 512 QAM technology. Northern Telecom's 512 QAM technology allows the capacity of six DS3's/STS-1's to be carried per 40 MHz radio channel, which is equivalent to 4032 voice channels."

ANS Comment: Noted. This appears to be the only current fixed point to point microwave radio product to require 40 MHz spectrum.

(4/1) "Therefore, the Commission should not adopt a migration plan that jeopardizes the high-density microwave routes presently operating in the 4 GHz, 6 GHz and 11 GHz bands."

ANS Comment: The purpose of this FNPRM is to facilitate the migration of low to moderate capacity 2 GHz users. Despite the merits of a new 40 MHz high capacity radio, its use is beyond the scope of this FNPRM.

(4/3) "Specifically, the Commission should not allow wideband and narrowband channels to coexist in the 3.7 to 4.2 GHz and the 5.925 to 6.425 GHz bands."

ANS Comment: The Commission has stated that these bands are available to place the existing 2 GHz users. The only issue is how this can be best accomplished. The sharing of narrowband and wideband systems proposed in the FNPRM is the preferable approach because this plan maximizes spectral efficiency and flexibility.

(5/1) "To the extent that there is a perceived need to allow both types of facilities in a single band, sharing the 10.7 to 11.7 GHz bands for wideband and narrowband channels is a preferable alternative."

ANS Comment: ANS does not concur. The expanded 10.5 GHz band, with its existing lower channel density channels, would be better suited. As Northern Telecom notes, high and low density users should not be mixed except when unavoidable. Inexplicably, Northern Telecom's proposal would compromise the use of your 40 MHz radio in this band.

(5/2, 6/1) "Northern Telecom suggests the standardization of 40 MHz channels in the 3.7 to 4.2 GHz band. A 40 MHz channel plan can be derived from and coordinated with the existing 20 MHz channelization plan."

ANS Comment: This is beyond the scope to the current FNPRM. We suggest that Northern Telecom address this issue.

(6/2) "Northern Telecom also proposes the standardization of 40 MHz wideband channels in that band, to permit the operation of very high capacity radios for typical common carrier multi-channel usage."

ANS Comment: This is beyond the scope to the current FNPRM.

(6/4) "... Northern Telecom supports the Commission's proposal to approach the NTIA to open formal discussions to determine whether some form of shared access to the 1.71 to 1.85 GHz and 3.6 to 3.7 GHz bands by common carriers and private operating fixed microwave users can be achieved."

ANS Comment: ANS concurs.

(7/1) "Northern Telecom agrees with the Commission's proposal to utilize current coordination procedures incorporated in Part 21 and Part 94 to govern the common carrier and private carrier usage, respectively. With respect to those Rules, Northern Telecom generally supports the current procedures for reservation of channel growth for the Part 21 wideband channel users."

ANS Comment: Noted.

(7/2) "Northern Telecom supports the adoption of the following new digital standards, while maintaining existing voice channel loading requirements and analog standards to minimize disruption of existing microwave radio systems. Also, a five year transition period after adoption of final rules should be allowed in order to minimize disruption."

Nominal Channel Bandwidth (MHz)	Minimum Payload Capacity (Mbits/s)	Minimum Traffic Loading Payload (as % of payload capacity)	Typical Utilization
1.25	3	n/a	2 DS1
2.5	6	n/a	4 DS1
3.75	12	n/a	8 DS1
5.0	18	n/a	12 DS1
10.0	44	50	1 DS3/STS-1
20.0	89	50	2 DS3/STS-1
30.0	134	50	3 DS3/STS-1
40.0	178	50	4 DS3/STS-1

ANS Comment: ANS does not concur. This is a reiteration of the Joint Commenters/TIA position. ANS concerns are discussed at length in Attachment A, Modified Plan at Sections 4-5.

(8/1) "For all bands, concatenation of multiple contiguous channels should be permitted as long as the minimum payload capacity requirements are met."

ANS Comment: ANS concurs.

(8/2) "Northern Telecom also fully supports the Commission's suggestion that the expansion of existing microwave systems should be allowed under current channelization plans without waiver. In addition, Northern Telecom agrees that the automatic transmit power control (ATPC) technique should be explicitly authorized

in Part 21 and Part 94 of the FCC rules, and Northern Telecom supports the proposed changes. Finally, with regard to the power mask rules, Northern Telecom urges continued use of the existing FCC mask under Part 21 and Part 94."

ANS Comment: ANS concurs.

(9/2) "Northern Telecom urges the Commission to adopt a 'two frequency' plan for operation of narrowband channels in common carrier and private operating fix bands between 3 and 11 GHz, which should allow twice the number of users in the same bandwidth as compared to a 'four frequency' plan. Northern Telecom proposes that in those bands, new users, as well as existing users converting from analog to digital or expanding their system, should be required to use a two frequency plan to make more spectrum available. Such requirement would make available adequate capacity using the alternative channelization plan proposed by Northern Telecom to allow the migration of users from the 2 GHz band without jeopardizing the benefits of high capacity wide bandwidth systems."

ANS Comment: ANS concurs. However, ANS must observe that the proposal only has meaning in a multichannel ("multiline") system. Most of the 2 GHz users will be using single channels. Within the context of this FNPRM, the comment is unnecessary. For cases where it applies, the use of "two frequency" plans is a standard frequency planning practice when high performance antennas are used (a proposal consistently mentioned by the common carriers and endorsed by ANS). If antenna standards are improved this will be accomplished by all frequency coordination organizations as a matter of course. See the attached article "External Interference, Introduction,." for more detail.

Public Broadcasting Service

(1/2, 2/1) "PBS's concern is that the proposed common carrier digital channel loading requirements, discussed at Paragraph 31 of the FNPRM and set forth in proposed Section 21.122(a)(2) of the Commission's Rules and Regulations, while perhaps appropriate for the voice channel systems for which they were developed, are inappropriate and burdensome for the digital links that will soon be needed to relay digitally encoded motion video material, such as compressed NTSC and Advanced Television System ("ATV") signals, to broadcasters, including links interconnected to satellite distribution systems."

ANS Comment: ANS concurs. Since digital transmission systems may be used for a wide range of legitimate nontelephony uses, voice channel loading requirements are not appropriate for any form of digital transmission. Digital transmission rate capacity, however, is appropriate.

(2/3, 3/1) "The Commission is currently embarked on an historic proceeding looking toward converting American television broadcasting from the analog NTSC

standard to a new digital ATV standard to be selected in MM docket No. 87-268. This impending change in television broadcast standards, together with new developments in video compression technology generally, will require the conversion of supporting transmission systems, including the microwave link between the PBS TOC and SOC, to digital operation."

ANS Comment: Noted.

(3/2) "When television broadcasting becomes digital, if not before then, PBS's entire distribution system, including the TOC-SOC interconnection link, will have to be converted permanently to digital operation. At that time, the link will presumably become subject to Section 21.122(a)(2). However, the efficiency standards in that section, while perhaps appropriate for voice telephone channels, will present serious problems if applied to television program distribution systems, because they require the use of a digital modulation scheme which is inconsistent with the modulation scheme used by communications satellites that either take a signal from a microwave link or deliver a signal to it."

ANS Comment: ANS does not concur. For the reasons noted below, this argument is technically flawed.

(3/3) "The proposed efficiency standard in Section 21.122(a)(2) requires the use of quadrature amplitude modulation ("QAM"). QAM, while highly efficient, requires highly linear amplifiers. However, highly linear amplifiers are not available on communications satellites, because they consume more power than is available in orbit. To be compatible with the non-linear amplifiers on satellites, earth stations will have to use quadrature phase shift keyed modulation ("QPSK") when uplinking television feeds."

ANS Comment: ANS does not concur. There is no technical reason for fixed point to point microwave radios to use the same spectrally inefficient modulation methods used by satellite transmission systems.

(4/1) "The terrestrial microwave entrance link to the earth station should be modulated in the same way as the earth station uplink. If QAM were required for the terrestrial link and QPSK for the satellite uplink, traffic would have to be reprocessed at the uplink and remodulated before being transmitted to the satellite. That process could introduce additional errors and would add complexity to system control and new costs to the program distribution chain. PBS could alleviate these problems to some extent by moving its TOC to the uplink location, but such a move would be impractical and would involve additional personnel and unnecessary expense and effort to coordinate operations at PBS headquarters in Alexandria and the remote TOC. The proper, effective, and efficient way to operate the public television distribution system is to create the program distribution feed in final digital form at the TOC at PBS headquarters and to have the entire distribution

system act as a transparent end-to-end pipeline all the way to the control rooms of individual public television stations."

ANS Comment: This is an interesting approach technically. However, PBS ignores the basics of modern digital microwave transmission. The system described is a multihop microwave system which is modulated at one location and transmitted over several hops without demodulation. This system is basically an analog radio with a digital modem. Such hybrid systems were used about ten years ago on analog systems requiring digital transmission. Since these systems were so sensitive to errors introduced by the multihop analog systems (very poor fade margin), these systems were soon replaced by real digital systems. Real digital systems accept a payload signal, convert it into a digital signal suitable for radio transmission, and transmit that signal. The digital signal is recovered and retimed on each radio hop. That is one of the ways the system avoids the introduction of errors that would be introduced by a multihop "analog" system. PBS will be hard pressed to find a vendor for the microwave radio it describes - and it is unlikely to enjoy the error performance on normal length paths if it does. If PBS buys high quality commercial microwave digital transmission equipment, it will convert the digitized video payload signal into a signal suitable for transmission, reconstitute that signal after every hop, and then reform the digital payload signal at the end location prior to connection to the satellite link. The digital terrestrial microwave path will be no different than any other commercial microwave link - and should be regulated like the others.

(5/2) "... PBS urges the Commission to provide an exception, perhaps by means of a footnote to Section 21.122(a)(2), stating that:

Microwave systems carrying digital motion video material, such as television programming, may use modulation schemes consistent with the modulation of the system into or from which their traffic is being fed, without regard to this subsection, provided that they comply with the 1 bit/sec/Hz requirement in Section 21.122(a)(1)."

ANS Comment: ANS does not concur. As noted above, there is no technical reason for this.

Pacific Telesis Group

(2/4) "Permitting Private Users Into the Common Carrier Will Severely Affect Spectrum Available for Common Carrier Use."

ANS Comment: ANS recognizes the need for more spectrum in several locations. That is our motivation for encouraging the dialog with NTIA for more spectrum. However, there is a demonstrated need for more low density channels. As noted below, Pacific Bell is on record as needing low density channels. Their need apparently is the same as the Private Users in many cases. This FNPRM would help Pacific obtain the channels they told NTIA (see below) they need.

(3/2) "Rechannelizing Broadband Frequency Pairs by Overlaying Narrowband Channels Promotes Broadband Underutilization. In its responses to the Alcatel Petition, Pacific objected to subdividing 30 MHz channels into 10 MHz channels. This objection should not be disregarded."

ANS Comment: Pacific's reasons for this position are unclear. It would help Pacific to put in the 1 to 8 DS1 payloads it desires (see below).

(4/2) "Pacific suspects that the Commission's required minimum loading levels would not be met by many of the current licensees within both the common carrier and the private point-to-point microwave services. The splintering of the 6 and 11 GHz channels will lead to further underutilization of this valuable and diminishing resource."

ANS Comment: ANS suspects that the Commission's required minimum loading levels will be met by many of the current licensees within both the common carrier and the private point-to-point microwave services. If Pacific has reason to suspect otherwise, we would appreciate understanding the basis of that suspicion. The industry has done without this further attempt at legislation. Splintering of the band will be minimized by the segregation imposed by this proposal in conjunction with prudent bunching of users by the frequency coordination organizations.

(5/2) "The Commission should disregard the suggestion that there is a diminishing need for 30 MHz broadband channels. Pacific Bell's recent employment of both 6 and 11 GHz channels gives strong testimony to the contrary."

ANS Comment: ANS notes that on November 6, 1992, Pacific Telesis commented to NTIA's Notice of Inquiry on Current and Future Requirements for the Use of Radio Frequencies in the United States. On the middle of page 7 of that document, Pacific declares that it "generally agrees that long haul terrestrial microwave route usage is declining in favor of fiber optics. However, short haul microwave is still a viable alternative for many applications, especially when man-made (including environmental problems, e.g. national and state parks) or geographical restrictions exist. For example, Pacific Bell has over 40 links of 2 GHz point-to-point microwave links operating in California with capacities ranging from 1 to 8 DS1s." The 30 MHz channels are typically long haul channels. Pacific Bell states that its recent channel deployment is low density (1 to 8 DS1s). This is strong testimony for allocating the low density channels proposed in the FNPRM. Pacific Bell seems to be the one suggesting there is a diminishing need for 30 MHz channels.

(5/3) "Pacific believes the only way to retain future broadband capability is to reserve at least half of the current 6 and 11 GHz common carrier bands exclusively for broadband (30 MHz) frequency pairs."

ANS Comment: ANS does not concur. Pacific's position is at variance with its position taken with NTIA, as noted above.

(5/4) "The proposal that future channels be reservable for periods as short as six months is unworkable."

ANS Comment: Noted.

(6/1) "It would be unreasonable to expect Pacific Bell to plan and invest in a microwave radio route, given the limit of reserving frequencies for known future growth to as brief a time as six months."

ANS Comment: Noted.

Satellite Broadcasting and Communications Association

(2/4, 3/1) "... the addition of up to 23,000 Private Operational-Fixed Microwave links at C-band would seriously aggravate the existing problem of terrestrial interference (TI) for the 3.9 million home satellite dishes (HSD) in this band."

ANS Comment: This is an acknowledged problem. It is truly unfortunate that the home satellite dishes, although legally accorded only secondary status, can seriously limit the use of the 4 GHz band by terrestrial microwave users accorded primary status.

(4/1) "1) That the Commission rescind its proposal to include the operational fixed service in the 3.7 - 4.2 GHz band and to exclude this band from further consideration on any basis, and 2) Set aside the other proposals in the present FNPRM until the Commission has had the time to review the entire set of issues raised by the emerging technology allocations and regulatory actions taken by WARC-92."

ANS Comment: ANS does not concur.

(12/1) "The Commission's Proposal to Rechannelize 4 GHz Fixed Service Operations Could Render HSD Use of the Band Impossible for Both Existing and New Installations. The HSD industry's ability to share the 4 GHz band with the existing Fixed Service transmitters, while difficult and expensive, is made possible today only because of the spectrum sharing plan developed some two decades ago by the FCC, and the fact that the number of FS operators is not increasing rapidly. This plan allows for an "off-set" of plus or minus 10 MHz between the "center frequency" of the satellite transponder and the Fixed Service carrier.

Sharing of the 4 GHz band is possible only as a result of this channelization plan and the subsequent order it has created in the utilization of this band."

ANS Comment: ANS has taken these concerns into consideration in the preparation of its revised frequency plans. See Attachment A, Modified Plan at Section 3.1.

(12/2) "Rechannelization would destroy the intricate and successful frequency 'offset' tool."

ANS Comment: A shrill comment without technical justification.

SR Telecom, Inc.

(ii/1) "The Commission's proposal to eliminate the 10.565-10.615/10.630-10.680 GHz ("10 GHz band") allocation from point-to-multipoint use in favor of private and common carrier fixed-microwave use, on a co-primary basis, is premature and ill advised."

ANS Comment: ANS does not concur. The point to multipoint market has failed to develop. The fixed point-to-point microwave market need is now.

(ii/2) "... SR Telecom urges the Commission to maintain the current 10 GHz allocation for point-to-multipoint services, since carriers will be able to satisfy the present demand for DEMS and DTS services with reliable low-cost equipment that will soon be available in the marketplace."

ANS Comment: When is soon? What is the market demand?

(iii/1) "... the 18 GHz band may not be suitable for DEMS and DTS operations due to adverse propagation and rain attenuation considerations."

ANS Comment: The 10.5 GHz band has similar limitations.

(iii/2) "In order to avoid such a harsh result, SR Telecom proposes two less drastic alternatives: (1) allocation of Channels 1 through 4 and 11 through 14 in the 10 GHz band for point-to-multipoint use on an exclusive basis; Channels 5 through 10 and 15 through 24 to be allocated to the fixed microwave services on a co-primary basis with the point-to-multipoint services, or (2) allocation of the 10 GHz band for fixed-microwave and point-to-multipoint use on a co-primary basis, with a requirement that fixed-microwave applicants demonstrate that no other frequencies outside the 10 GHz band are available for the proposed systems."

ANS Comment: ANS does not concur. The point to multipoint market has failed to develop. The fixed point-to-point microwave market need is now.

Telecommunications Industry Association Fixed Point to Point Communication Section

The technical issues raised by TIA are addressed in other sections of this reply comments document. The operational policy issues should be resolved by the user community, not by the manufactures.

ANS would like to make it clear that it enthusiastically supports TIA as an organization. ANS engineers serve as chairman of the Fixed Point to Point Section and well as chairman of three out of four of the technical committees formed by the Section (including chairman of TR 14.11, the committee which formulates TIA bulletin 10). Unfortunately, ANS finds itself at odds with other TIA members regarding this FNPRM.

Generally the industry manufacturers are able to consolidate their position via TIA section documents. Unfortunately, in this case, there is significant disagreement within the manufacturing industry regarding whether or not spectrally efficient equipment should be used in this FNPRM. The similarity between the TIA position and that of the Joint Commenters, Harris-Farrinon, DMC, and Telesciences, is clear. The current TIA position, rather than the usual consensus, is the position of the majority - but not all - of the member companies. The TIA position maintains the status quo regarding spectrum efficiency and attempts to restrict use of wide band radios produced by a minority of the TIA manufacturers. It also proposes in channel plans (15 and 40 MHz) to support particular manufacturer's products without regard to the needs of 2 GHz users.

The TIA position should not be regarded as an industry consensus.

United States Telephone Association

(2/2) "Given the proliferation of 4 GHz satellite down links, the use of 4 GHz frequencies may be severely restricted on all channels except those growth channels that have been secured through the prior coordination process. Because of such constraints, the 4 GHz band may prove to be less attractive to relocated 2 GHz licensees."

ANS Comment: ANS concurs.

(2/3, 3/1) "USTA supports the proposed plan. A station licensed under the new plan, transmitting on the upper or lower half of the band, could potentially interfere with receivers on both ends of a victim path. Grandfathering established growth plans may be necessary to avoid interference created by the proposed frequency changes in areas where there are 4 GHz licensees operating on the existing plan."

ANS Comment: ANS has taken this concern into account in formulating the proposed revised frequency plans. See Attachment A, Modified Plan at Section 3.1.

(3/2) "The proposed 6 GHz rechannelization plan specifies a 30 MHz bandwidth as opposed to the existing 29.65 MHz bandwidth. The frequency offset of the new channels varies from 200 kHz to 2.2 MHz. This variation will create a carrier beat interference potential between analog systems, particularly in congested areas. Grandfathering current frequency growth plans may be necessary."

ANS Comment: ANS has taken this concern into account in formulating the proposed revised frequency plans. See Attachment A, Modified Plan at Section 3.2.

(4/1) "USTA recommends that the Commission encourage potential 6 GHz analog licensees to use the upper portion (6525-6875 MHz) of the band which is currently allocated for narrowband use, particularly if the system requires 10 MHz or less of bandwidth. This will preserve the integrity of the remainder of the 6 GHz band for common carrier use, which is primarily wideband. Analog systems with bandwidths greater than 10 MHz should be encouraged to adhere to the proposed channel plan where feasible. Licensing based on the existing plan should be permitted in other instances. In addition, systems with bandwidths of 10 MHz or less should also be required, initially, to use frequencies currently allocated for narrowband systems. If channel availability precluded narrowband use of the upper 6 GHz frequencies, the lower portion of the band could be utilized, as outlined in the proposed rechannelization plan. Grouping like systems will promote spectrum efficiency and ease coordination."

ANS Comment: This recommendation seems reasonable and should be encouraged by industry and the Commission.

(4/2) "The proposed 11 GHz rechannelization plan decreases the bandwidth from 40 MHz to 30 MHz. This plan promotes spectrum efficiency, yet may be technically feasible only for new routes. The Commission should allow, therefore, for the grandfathering of frequency plans currently in place. Channel additions may be difficult, if not impossible, on some routes unless grandfathering is permitted. Growth plans should continue to be coordinated and harmonized to promote spectrum efficiency."

ANS Comment: ANS concurs.

(5/1) "USTA agrees with the Commission that this proceeding should not be delayed pending negotiations with the National Telecommunications and Information Administration for access by non-government licensees to the 1.71 to

1.85 GHz government band. However, USTA urges the Commission to continue to vigorously pursue this issue and to make every effort to obtain access to adjacent government bands."

ANS Comment: ANS concurs.

(5/2) "The technical characteristics of the government band adjacent to the bands to be allocated for emerging technologies are almost identical. Therefore, relocation to these government bands is not only appropriate, but desirable."

ANS Comment: ANS concurs.

(5/3) "Common carriers secure future growth channels through the prior coordination process. This process has proved to be invaluable for establishing long range growth plans, particularly in frequency congested areas. This procedure has also assisted in eliminating potential interference."

ANS Comment: Noted.

(6/3, 7/1) "The Commission proposes to establish common carrier coordination procedures for all the shared bands except the upper 6 GHz band (6525-6875 MHz), which is currently limited to private use. Rather than maintaining two sets of rules, the Commission should adopt consistent coordination procedures. Without such rules the upper 6 GHz band could potentially become a haven for licensees who choose the upper 6 GHz band to avoid the 30 day notification period. The Commission should adopt the common carrier prior coordination procedures for all bands."

ANS Comment: This should be considered by all potential users.

(7/2) "USTA recognizes the need for the swift development of interference standards governing equipment and frequency separation combinations. The Telecommunications Industry Association working group (TIA 14.11) as well as the National Spectrum Managers Association are currently addressing these issues. These processes are open to all users and manufacturers. The Commission should encourage these groups to continue their efforts."

ANS Comment: ANS concurs.

(7/3) "USTA supports the development of uniform antenna standards in all frequency bands for both common carrier and private microwave users. Allowing licensees to utilize Category B antennas could lead to further congestion and require new entrants to coordinate around systems with substandard antenna systems. The Commission should update and improve the Category A standards

for use by all carriers. This will maximize spectrum efficiency and permit full usage of available frequency bands."

ANS Comment: ANS concurs.

(8/1) "USTA agrees that automatic transmit power control (ATPC) should be permitted under both Part 21 and Part 94 of the Commission's rules. However, USTA believes that a uniform rule should incorporate the current standards for common carriers. Maximum transmit power should not be exceeded under any circumstance. Established industry bodies should be permitted to establish the appropriate procedures to be used in dealing with ATPC systems during interference analysis."

ANS Comment: ANS concurs.

Utilities Telecommunications Council

(3/2) "UTC supports the Commission's basic proposals in the FNPRM, as they are generally consistent with the proposals that UTC and Alcatel suggested in their petitions."

ANS Comment: ANS concurs.

(5/2) "Accordingly, UTC urges the Commission not to require loading standards for private microwave systems operating in any of the bands above 3 GHz. In the alternative, the Commission should not enforce loading standards on private microwave systems operating on bandwidths of less than 10 MHz."

ANS Comment: ANS concurs.

(5/3) "UTC supports the Commission's proposal to rechannelize the 3.7-4.2 GHz (4 GHz) band."

ANS Comment: ANS concurs.

(7/3, 8/1) "UTC therefore urges the Commission to follow through with its commitment to pursue discussion with NTIA regarding the introduction of fixed microwave operations into the 3.6-3.7 GHz band."

ANS Comment: ANS concurs.

(9/2) "Accordingly, UTC urges the Commission to renew its efforts in expediting its negotiations with NTIA regarding access to the 1710-1850 MHz bands by

displaced 2 GHz microwave users. Moreover, the Commission should adopt specific procedures for 2 GHz microwave users to request access to the 1710-1850 MHz band."

ANS Comment: ANS concurs.

(9/3, 10/1) "In its Comments on the Alcatel petition UTC supported retention of the existing coordination rules for each microwave band. However, on further review, UTC believes that the coordination procedures and technical rules for the shared microwave bands should be consistent to eliminate any regulatory incentive for licensees to seek access to one band over another. At present, the principle difference between common carriers and private microwave coordination is the requirement, at Section 21.100, for common carrier applicants to serve "prior coordination notices" on potentially affected applicants and licensees, and to wait for responses before filing applications with the FCC. These requirements increase the cost of frequency coordination and delay applicants' ability to commence operation and could serve as a catalyst for most applicants to select the upper private 6 GHz band due to its streamlined coordination procedures. It would appear that the easiest way to make the coordination procedures consistent is to impose the common carrier prior coordination notification requirements of Section 21.100 on applicants for the upper 6 GHz microwave band."

ANS Comment: ANS concurs.

(10/2, 11/1) "... with the significant increase in bandwidth available to carriers under the proposed channelization plan, there is no need for carriers to retain the ability to reserve growth channels on an indefinite basis. While coordinators should be encouraged to avoid blocking other users' access to growth spectrum, there is no reason for the FCC to institutionalize the warehousing of spectrum by permitting repeated renewals of coordination notifications."

ANS Comment: This is a sensitive area requiring careful review by the entire user community.

(11/2) "UTC is absolutely opposed to any degradation of the existing private microwave interference standards that would impair the reliability of private microwave operations. UTC recognizes that the common carrier and private microwave interference standards are converging and supports the adoption of consistent standards across all of the shared bands, provided system reliability is not compromised. To the extent that the interference standards currently differ, UTC recommends that the Telecommunications Industry Association (TIA) be recognized as the appropriate entity to develop consistent interference standards. Further, until such time as uniform interference criteria are adopted, UTC suggests that the FCC require coordinators to apply the interference criteria utilized by the majority of the users of a particular band."

ANS Comment: ANS concurs.

(12/1) "... UTC urges the Commission not to adopt rules that would inhibit or preclude the use of analog microwave equipment in the bands above 3 GHz."

ANS Comment: ANS concurs.

(12/2) "... UTC urges the Commission to clarify, as discussed above, that these analog loading limits do not apply to Part 94 applicants."

ANS Comment: ANS concurs.

Western Telecommunications, Inc.

(3/2) "Existing systems should be permitted to expand on existing frequency plans."

ANS Comment: ANS concurs. This is no longer an issue with the revised frequency plans. See Attachment A, Modified Plan at Sections 3-6.

(3/3) "WTCI therefore requests that a footnote or subsection be added to Section 21.701 of the Rules as follows:

"Frequency and channelization plans of common carrier systems operating in the 4, 6 and 11 GHz bands on _____ are grandfathered, and new channels may be added to those systems notwithstanding the channelizations prescribed in the Rules."

ANS Comment: ANS concurs. This is no longer an issue with the revised frequency plans.

(3/4, 4/1) "Thus, the purpose of the grandfathering provision would be to enable carriers to use their existing systems and channelization plans for added or new services without being forced to change frequency plans and/or equipment to meet the new bandwidths and channel limitations proposed by the Further Notice.

ANS Comment: ANS concurs. This is no longer an issue with the revised frequency plans. See Attachment A, Modified Plan at Sections 3-6.

(4/2) "The alternate channel provision should be amended to permit expansion on existing polarizations. As presently proposed, a common carrier system operating on, for example, a vertical polarization plan of vertical channels 1, 3, 5 and 7 and horizontal polarization channels 2, 4, 6 and 8 would be required to incur the

additional expense of adding horizontal polarization before using channel 7 as part of its expansion from a three channel to a four channel system. Accordingly, WTCI requests that the footnotes in Section 21.701(d)(6) and (e)(6) be changed to read as follows:

1. Alternate channels. These channels are set aside for narrow bandwidth systems and should be used only if all other channels are blocked, provided however that such alternate channels may be used to avoid the adding of the opposite polarization."

ANS Comment: ANS concurs. This is no longer an issue with the revised frequency plans. See Attachment A, Modified Plan at Sections 3-6.

(5/1) "WTCI supports the frequency coordination proposals in the Further Notice to the effect that private microwave users operating in the 4, 6 and 11 GHz common carrier bands are to follow and be bound by the prior coordination procedures set forth in Section 21.100(d) of the Rules, and that common carriers operating in the 6 and 10 GHz private bands would be governed by the frequency coordination procedures to proposed Section 94.63(a) of the Rules."

ANS Comment: ANS concurs.

(6/2) "Thus, the reservation of future growth channels requires strict compliance with industry adopted notification and coordination procedures, and these procedures have served the industry and the public well over the years and have fostered the development of efficient and economical common carrier networks throughout the country. Accordingly, there is no need for changes in the frequency coordination Rules (Part 21.100(d)) to cover the reservation of future growth channels, and the Commission is correct in not proposing such changes in the Future Notice, Appendix A."

ANS Comment: Noted. This should be discussed and resolved by the user community.

(7/1) "As set forth above, WTCI supports the Commission's proposal to require private users operating in the common carrier bands to comply with the frequency coordination procedures of Section 21.100(d) of the Rules and conversely requiring common carriers operating in the private carrier bands to follow Section 94.63(a) of the Rules. WTCI also agrees that the frequency interference standards of Part 21 of the Rules should apply to private users in the common carrier bands and those set forth in Part 94 should apply to carriers operating in the private carrier bands."

ANS Comment: ANS concurs.

(7/2) "WTCI concurs with the Commission's proposal to maintain the existing analog loading and performance standards in Part 21 of the Rules."

ANS Comment: ANS concurs.

(7/3, 8/1) "While WTCI operates thousands of route miles of digital message systems and has not experienced any problems relating to standards, WTCI has no objection to the Commission's proposal in the Further Notice to add loading and performance standards for digital radio systems."

ANS Comment: ANS concurs.

(8/2) "WTCI notes with approval that the Commission in several instances in the Further Notice has indicated that a liberal waiver policy will be followed to accommodate situations occasioned by the proposed new restrictions and limitations on common carrier operations. Because of the multitude of existing systems and considerable equipment on hand, there will be situations where waivers are in order to avoid inefficient or uneconomical carrier operations and to provide the lowest cost service to the public. For example, WTCI in the future in a number of instances will be adding extensions to its trunkline route to serve additional cities and areas. The most economical way of providing such service extensions will be through the use of existing equipment in its inventory which is tuned to its existing frequency and channelization plans. In these types of situations, unless such extensions of existing systems are deemed to be grandfathered, waivers of the proposed bandwidth limitations and channelizations would be warranted and should be readily granted by the Commission."

ANS Comment: ANS concurs. This is no longer an issue with the revised frequency plans. See Attachment A, Modified Plan at Sections 3-6.

Appendix C

Technical Background Articles

System Design Concepts

System Design Considerations for Line of Sight Microwave Radio Transmission

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INTRODUCTION

Microwave system design is a tradeoff of many factors. Some of those are a function of state of the art equipment parameters. Other factors are independent of equipment design. Considerable attention is placed on transmission bandwidth and system gain. However, it is often the equipment independent factors which dominate overall system performance. Those factors are overviewed in this paper.

SYSTEM DESIGN

Detailed radio system design is done on the basis of interference noise limits and transmission path loss objectives. The data necessary to estimate terrestrial microwave interference is listed in Table 1. Based on this data, carrier to interference objectives are established. The estimation of interference noise requires a knowledge of the desired signal (carrier) power, C , and the undesired interfering signal power, I . If the desired signal originates at station A, transmitting toward station B, and the interfering signal originates at station C, transmitting toward D, then the C/I observed at station B is given by

$$C/I(\text{dB}) = P(\text{dB}) + G(\text{dB}) + L(\text{dB}) + D(\text{dB})$$

$$P(\text{dB}) = \text{transmitter power differential}$$

$$= P_c(\text{dBm}) - P_i(\text{dBm}) - L_c(\text{dB}) + L_i(\text{dB})$$

$$G(\text{dB}) = \text{antenna gain differential}$$

$$= G_c(\text{dB}) - G_i(\text{dB})$$

$$L(\text{dB}) = \text{free space loss differential}$$

$$= 20 \log (d_i/d_c)$$

$$D(\text{dB}) = \text{antenna discrimination}$$

$$= D_c(\text{dB}) + D_i(\text{dB})$$

$$P_c = \text{transmitter power of desired signal}$$

$$P_i = \text{transmitter power of undesired signal}$$

$$L_c = \text{power loss of desired signal between transmitter and transmit antenna}$$

$$L_i = \text{power loss of undesired signal between transmitter and transmit antenna}$$

$$G_c = \text{gain of transmit antenna at site A toward site B}$$

$$G_i = \text{gain of transmit antenna at site C toward site D}$$

$$D_c = \text{discrimination (relative to main lobe power) of receive antenna at site B toward site C}$$

$$D_i = \text{discrimination (relative to main lobe power) of transmit antenna at site C toward site B}$$

$$d_c = \text{distance from site A to site B}$$

d_i = distance from site C to site B

For adjacent channel interference noise calculations on a multiline parallel route system, the C/I equation reduces to the combined cross-polarization discrimination (XPD) of the transmit and receive antennas. The combined XPD is never better than the worse of the two antennas. Based on a calculated C/I, an estimate is made of interference noise. The interference depends on both the desired signal as well as the interfering signal. Figures 1 and 2 show examples of noise produced in an FM radio from FM or digital signal interference. The preceding formula assumed free space transmission. Some interference cases may require calculation of obstruction or rain scatter loss. Adjacent channel interference requires an estimate of relative fading of the C and I signals. Obviously antenna and transmission path performance is crucial to optimizing the C to I objectives. Tables 2 and 3 list typical ranges of C/I for interfering signals which have the same (cochannel) or slightly different (adjacent channel) interfering frequency. These tables are based on Interference Objective Tables, Issue 7, revised August 1989, of Working Group 5 of the National Spectrum Managers Association. The FM or SSB system objectives are based on a foreign system interference allocation of 4 dBmC0 (5 pWC0) per exposure for carrier-sideband interference and 17 dBmC0 (50 pWC0) per exposure for carrier-beat interference (with an assumed 10 dB burble factor). Digital C/I objectives are based on a allocation of 30 dB C/I per exposure for foreign system interference. Paths below 10 GHz have an assumed 40 dB (multipath) fade margin while those above 10 GHz have a 50 to 55 dB (multipath plus rain) fade margin. Objectives are to be met when the desired signal is in a deep fade and the foreign interference is experiencing an correlated 10 dB fade.

ANTENNA RADIATION PATTERNS

Frequency reutilization and interference reduction is directly related to antenna radiation pattern performance. An antenna is a device for transmitting or receiving electromagnetic signals through space. In discussions of antenna gain, the concept of an isotropic radiator (isotrope) is fundamental. Essentially an isotrope is an antenna that radiates uniformly in all directions of space. Its pattern is a perfect spherical surface in space; that is, if the electric intensity of the field radiated by an isotrope is measured at all points on an imaginary spherical surface with the isotrope at the center (in free space), the same value will be measured everywhere.

A nonisotropic antenna will radiate more power in some directions than in others and therefore has a directional pattern. Any directional antenna will radiate more power in its direction (or directions) of maximum radiation than would an isotrope (with both radiating the same total power). The

directive gain of an antenna is defined, in a particular direction, as the ratio of the power density radiated in that direction, at a given distance, to the power density that would be radiated at the same distance by an isotrope radiating the same total power.

At microwave frequencies, the main type of antenna for transmission is a large parabolic reflector feeding or feed by a small horn antenna. The horn is constructed and placed in such a way that the energy field across the parabolic reflector is greatest at the center of the reflector and tapers to a lower value (typically -10 dB) at the reflector edge. Although this illumination tapering reduces antenna efficiency, it also reduces the side lobe level (spurious responses) which make frequency reuse more difficult. Passive flat plane reflectors, either elliptical or rectangular shaped, may be used in the path to change direction of transmission. The field across the passive reflector is uniform. This causes the reflector to have high efficiency but poor side lobe performance. Sometimes the relatively inefficient parabolic antennas are used back to back as a passive repeater to avoid this side lobe (frequency reuse) problem.

The far field relative radiation pattern of a circular parabolic antenna (circular aperture) is a function of the illumination of the circular reflector. Sciambi [29] used Silver's [30] uniform and fully tapered parabolic illumination results to develop field patterns for arbitrarily tapered illuminations. The circular antenna patterns are given in Fig. 3. The 10dB tapered pattern is typical of commercial parabolic antennas.

- G_0 = normalized power intensity
- D = diameter of the circular aperture
- λ = free space wavelength
 - = $1/[1.0167 f(\text{GHz})]$ in feet
 - = $1/[3.3356 f(\text{GHz})]$ in meters
- f = radio frequency of operation
- θ = azimuth of measurement relative to path of maximum transmission

The far field relative radiation pattern for a circular reflector can be obtained directly from the results for a parabolic antenna with uniform illumination. The far field relative radiation pattern of a rectangular passive reflector can be obtained from Silver's results [30]. The far field radiation patterns for circular and square passive reflectors (uniformly illuminated apertures of projection) are plotted in Figs. 4 and 5.

L = width of the reflector

ϕ = rotation of the passive reflector in the plane orthogonal to the direction of wave propagation ($\phi = 0$ when the width dimension is parallel to the earth)

Note in Figure 5 as the rectangular reflector is rotated from the parallel to the earth position, the nulls move to the right and the side lobe peak levels are reduced. The side lobe reduction is a complicated function of the amount of rotation. If ϕ is zero, the pattern is not a function of the height/width ratio. As noted in Fig. 6, for ϕ of 45 degrees, the pattern is only mildly sensitive to the passive height/width ratio R . Fig. 4 shows that for $\phi = 0$, the far field radiation pattern of a rectangular reflector is significantly worse than that of a circular reflector antenna. However, comparison of Figs. 4 and 5 shows that if the rectangular reflector is rotated, its far field radiation pattern (in one plane) can be significantly better than a similarly sized circular reflector antenna.

The preceding antenna far field radiation patterns were based on assumed field amplitude distributions across the antenna aperture. For a passive reflector, the radiation patterns for uniform illumination are generally accurate since the reflectors are usually in a far field condition. These patterns can be distorted by secondary reflections due to terrain as well as moving the reflector into the near field of the illuminating antenna. For center-fed parabolic antennas, these patterns are never quite achieved. The aperture illumination distribution is complicated by the feedhorn design necessary to achieve that distribution. In addition, the near side lobe level (as well as overall gain) is affected adversely by blockage of the aperture by the feedhorn mechanical assembly. The low level wide-angle side lobe level is generally dominated by feedhorn spillover, rim diffraction, and reradiation and diffraction by the feedhorn support structure.

The results for the passive reflectors were developed assuming the passives to be oriented directly orthogonal to the path of transmission (uniform phase illumination). If the passive is rotated in a plane which includes the line of maximum power transmission, a linear phase error is introduced onto the aperture illumination. This causes the main beam to rotate and broaden relative to the

uniform phase case. From the point of view of an observer, the result is exactly the same as a passive reflector oriented directly orthogonal to the path of transmission but which has the area of the projection of the original passive into that orthogonal plane of reference.

FREE SPACE TRANSMISSION LOSS

An isotropic source is a hypothetical radiator which transmits or receives power equally in all directions. In an infinite homogeneous lossless medium, the power density P at a distance d from an isotropic source is the total power transmitted W_t divided by the surface area of a sphere with radius d . The power received W_r , by a receiving antenna with effective area A_r , is the product of A_r and P . The free space loss is defined as W_r/W_t .

$$L(\text{dB}) = 10 \log (W_r/W_t)$$

The formula is more commonly expressed in decibels in one of the following ways:

$$\begin{aligned} L(\text{dB}) &= -74.3 + 20 \log f(\text{GHz}) - 20 \log d(\text{miles}) \\ &\quad + 10 \log A_t(\text{ft}^2) + 10 \log A_r(\text{ft}^2) - T_t(\text{dB}) - T_r(\text{dB}) \\ &= -49.5 + 20 \log f(\text{GHz}) - 20 \log d(\text{km}) \\ &\quad + 10 \log A_t(\text{m}^2) + 10 \log A_r(\text{m}^2) - T_t(\text{dB}) - T_r(\text{dB}) \end{aligned}$$

Transmission line losses are significant at microwave frequencies and must be accounted for. T_t is the transmission line loss between transmitter and transmit antenna and T_r is the transmission line loss between receive antenna and the receiver. A_x is the effective area of projection of the antenna aperture in the direction of transmission and δ be the antenna efficiency. If the transmit antenna has axial gain (relative to an isotropic radiator) G_t and effective area A_t and the receiving antenna has axial gain G_r (relative to an isotropic radiator) and effective area A_r , the free space transmission loss formula [10] becomes

$$\begin{aligned} L(\text{dB}) &= -96.6 - 20 \log f(\text{GHz}) - 20 \log d(\text{miles}) \\ &\quad - T_t(\text{dB}) + G_t(\text{dB}) + G_r(\text{dB}) - T_r(\text{dB}) \end{aligned}$$

$$= -92.4 - 20 \log f(\text{GHz}) - 20 \log d(\text{km})$$

$$- T_t(\text{dB}) + G_t(\text{dB}) + G_r(\text{dB}) - T_r(\text{dB})$$

where antenna gain is given by

$$G_x(\text{dB}) = +11.1 + 20 \log f(\text{GHz}) + 10 \log A(\text{ft}^2) + 10 \log (\delta)$$

$$= +21.5 + 20 \log f(\text{GHz}) + 10 \log A(\text{m}^2) + 10 \log (\delta)$$

The typical value of δ varies from 0.45 to 0.55 for commercial parabolic antennas and 0.90 to 1.0 for passive reflectors. For parabolic antennas, A is merely the frontal area ($\pi \times \text{diameter}^2 / 4$) of the reflector since the antenna is aligned in the direction of transmission. For passive reflectors, A is the area of the passive projected onto a plane passing through the passive which is orthogonal to the direction of transmission. For a passive reflector, the effective area is the total surface frontal area multiplied by $\cos(C/2)$ where C is the angle formed by the two transmission paths which converge at the reflector.

The above loss formulas are commonly written as the following:

$$L(\text{dB}) = -T_t(\text{dB}) + G_t(\text{dB}) + \alpha(\text{dB}) + G_r(\text{dB}) - T_r(\text{dB})$$

$$\alpha(\text{dB}) = \text{free space loss}$$

$$= -96.6 - 20 \log f(\text{GHz}) - 20 \log d(\text{miles})$$

$$= -92.4 - 20 \log f(\text{GHz}) - 20 \log d(\text{km})$$

It is quite common to use one, two, or more passive reflectors between a transmitter and a receiver. One can treat each path independently. The reflector acts as a receiver in one direction and a transmitter in the other. The gain is, of course, the same in either case. The 2-way repeater gain referred to by some authors is the sum of the receive and transmit gain (expressed in dB) of the repeater.

The preceding formulas assume that all antennas are far enough from each other that far field conditions apply. Lewis, as reported by Friis [10], suggested that far field conditions exist as long as

$$\delta > 2a^2/\lambda$$

where d is the distance between the antennas, a is the largest linear dimension (in the plane of projection of the wave) of the larger antenna, and λ is the wavelength of the radio wave. As the antennas are moved closer together, the gain of the two antennas is reduced compared to the far field gain. The case of parabolic antennas was addressed by Bickmore and Hansen [2] for the case where one antenna is much larger than the other (only the large antenna is in the near field). Pace [28] gives an approximation for parabolic antennas of similar size. Based on these results, Fig. 7 was produced. This figure graphs the loss in composite antenna gain relative to far field gain as a function of D_a and D_b , the diameters of the two parabolic antennas. $D_a \geq D_b$ and the above parameter definitions apply.

It is common to estimate total path loss through a passive repeater as two independent paths. Often one end of the path has the reflector and/or parabolic antenna in the near field reducing effective free space gain. Jakes [13] considered the case of a parabolic antenna and elliptical (circular projection) reflector. Medhurst [24] produced a result for both the elliptical (circular projection) and rectangular (square projection) reflector cases. Based on Medhurst's results, Figs. 8, 9, 11 and 12 were produced. They represent the loss in composite antenna and reflector gain when the two approach each other. D_r is the diameter or width of the projection of the reflector in a plane parallel to the parabolic antenna. D_a is the diameter of the primary parabolic antenna.

Sometimes a pair of rectangular passive reflectors are used to go over or around obstructions. Although this case may be analyzed as three independent paths, typically the two passive reflectors are in each others near field. Wang [34] analyzed this case of two rectangular (square projection) passive reflectors in the transmission path. Figs. 10 and 13 show the loss in combined far field gain (relative to the gain of a single smaller reflector) as the two passive reflectors are moved close together. It is assumed that the projection of each rectangular passive in the plane orthogonal to the direction of transmission is square. A is the width of the square projection of the smaller reflector and B is the width of the square projection of the larger reflector. To use Fig. 10, work the problem as the loss of two independent paths with the smaller reflector as a single reflector and add the loss from Fig. 10. Many engineers prefer to treat passive reflector or double reflector problems as a combined gain problem. That may be accomplished through the use of Figs. 11, 12 and 13.

Note that all rectangular reflectors are assumed to have a square shape when projected into the path of transmission. If they are rectangular, the width used in the figures is the larger of the two rectangular dimensions. All elliptical reflectors are assumed to have a circular projection. If they are elliptical, the large dimension is used for the diameter. In all cases, however, the actual projection area is to be used to calculate far field gain.

PATH LOSS CALCULATION EXAMPLES

The general expression for path loss between transmitter T and receiver R may be written as follows:

$$P_r = P_t + L$$

$$P_r(\text{dB}) = \text{power received at R}$$

$$P_t(\text{dB}) = \text{power transmitted at T}$$

$$L(\text{dB}) = \text{path loss (expressed as gain) between T and R}$$

Direct Path Loss

Consider a typical 30 mile 6.2 GHz path with 10 foot parabolic antennas and 100 feet of elliptical waveguide at each site.

$$L = -T_r + G_t + \alpha + G_r - T_r$$

$$T_r = T_t = 1.2 \text{ dB}/100 \text{ ft} \times 100 \text{ ft} = 1.2 \text{ dB using the data in Table 5.}$$

$$G_t = G_r = 43.1 \text{ dB using data from Table 4 since we are not sure of the parabolic antenna efficiency (52% in this case).}$$

$$\alpha = -96.6 - 20 \log(6.2) - 20 \log(30) = -141.9 \text{ dB}$$

$$L = -1.2 + 43.1 - 141.9 + 43.1 - 1.2 = -58.1 \text{ dB}$$

Single Passive Repeater Loss (back to back parabolic antennas)

Let us suppose that the above 30 mile path must have a passive repeater. Let us further assume the passive is a pair of back to back parabolic 10 foot antennas in the middle of the path.

$$L = -T_t + G_t + \alpha_1 + G_{rr} - T_{rr} + G_{tr} + \alpha_2 + G_r - T_r$$

$$G_{rr}(\text{dB}) = \text{passive receive antenna gain}$$

$$G_{tr}(\text{dB}) = \text{passive transmit antenna gain}$$

$$T_{rr}(\text{dB}) = \text{line loss between the passive repeater antennas}$$

$$\alpha_1 = \text{free space loss between the transmitter site and the passive site}$$

$$\alpha_2 = \text{free space loss between the passive site and the receiver site}$$

$$T_t = T_r = 1.2 \text{ dB as before.}$$

$$T_{rr} = 0.5 \text{ dB (assumed value)}$$

$$G_t = G_r = G_{rr} = G_{tr} = 43.1 \text{ dB since all antennas are 10 foot parabolics.}$$

$$\alpha_1 = \alpha_2 = -96.6 - 20 \log(6.2) - 20 \log(15) = -135.9 \text{ dB}$$

$$L = -1.2 + 43.1 - 135.9 + 43.1 - 0.5 + 43.1 - 135.9 + 43.1 - 1.2 = -102.3 \text{ dB}$$

This is quite an increase in path loss. Overall loss becomes less as the passive repeater is moved toward one end of the path. Therefore, let's assume the passive is 500 ft from the receive site. The loss formula is the same except we have a near field correction term $N_2(\text{dB})$.

$$L = -T_t + G_t + \alpha_1 + G_{rr} - T_{rr} + G_{tr} + \alpha_2 + N_2 + G_r - T_r$$

$$\alpha_1 = -96.6 - 20 \log(6.2) - 20 \log(29.9) = -141.9 \text{ dB}$$

$$\alpha_2 = -96.6 - 20 \log(6.2) - 20 \log(0.0947) = -91.9 \text{ dB}$$